Evaluating Drift when Spraying an Active Ingredient Tank Mix Solution with and without Additional Adjuvants

R.E. Wolf[1], S.M. Bretthauer[2], B.K. Fritz[3], W.C. Hoffmann[3]

Wolf Consulting & Research, Mahomet, IL[1]; University of Illinois, Urbana, IL[2]; USDA ARS APMRU, College Station, TX[3]

Abstract

The impact of different spray tank modifiers into an active ingredient spray mixture on spray atomization and in-field behavior under aerial application conditions were examined. Wind tunnel tests demonstrated that active ingredient solutions potentially result in significantly different atomization characteristics from the typical water and non-ionic surfactant “blank” reference sprays used. Most spray adjuvants added showed little impact on the resulting atomization properties, however the polymers (polyvinyl and guar gum) tested widened the droplet size distribution. The field evaluation highlighted the difficulty of comparing a large number of spray formulations or treatments even when every effort was made to minimize time between replications. These results have led the authors to conclude that field testing of potential DRTs under aerial application conditions will be cost prohibitive and likely would give highly variable results. Wind tunnel evaluations at certified laboratories offer a much quicker and inexpensive method for evaluating large numbers of nozzle and spray formulation treatments. Overall the results of this study highlight the need to further investigate the interaction of active ingredient spray formulations and spray tank modifiers under high speed air shear atomization conditions to better understand the potential role and benefit that adjuvants play in aerial applications.

Keywords**:** drift, drift reduction technology, spray droplet sizing, active ingredient, spray adjuvants

Objective

The objective of this work was to evaluate spray fate and off-target transport from active ingredient spray formulation treatments made with and without additional spray adjuvants. Testing included both a high speed wind tunnel and a field drift study component. The high speed wind tunnel component assessed droplet size for a large number of spray formulations and was used both for modeling spray drift with AGDISP as well as used to select a limited subset of formulations that were evaluated in the field component.

High Speed Wind Tunnel Testing

Atomization testing was conducted in the USDA ARS Aerial Application Technology high speed wind tunnel, which has an operational range from 15 to 215 mph (Fig. 1). The spray nozzles tested were mounted on the boom similar to how they would be configured on the aircraft boom. The boom section is plumbed to a pressurized spray container to develop spray pressure and provide solution flow to the nozzle. Initial spray testing was completed for 33 individual spray treatments spanning three nozzles and 16 spray formulations. The three nozzles tested included a 110 degree flat fan with an 03 orifice, which was tested with water and a non-ionic surfactant only (NIS), (Spray Systems, Wheaton, IL), a 40 degree flat fan with a #12 orifice mounted in a CP Products 11TT nozzle body (CP Products, Tempe, AZ) , and an ASC rotary atomizer set to the D-12 orifice and a blade setting of 2. Droplet sizing was conducted at 137 mph airspeed for each of the treatments identified.

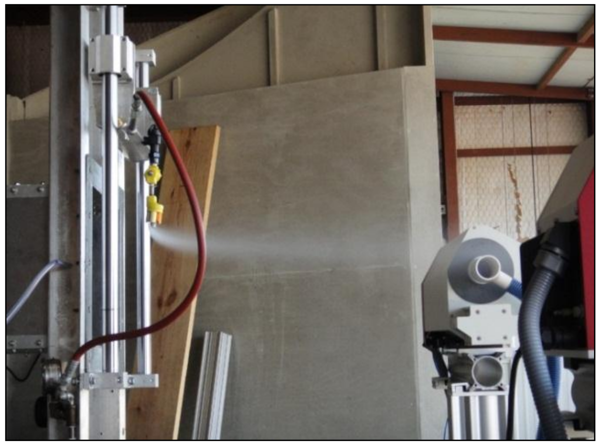

Figure 1. Wind tunnel outlet, nozzle mount and traverse and laser positioning.

Droplet size measurements were made using a Sympatec HELOS laser diffraction droplet sizing system (Sympatec Inc., Clausthal, Germany) which was positioned approximately 1.2 m downstream of the spray nozzle outlet to insure full atomization of the spray. For each treatment a minimum of three replicated measurements were made. After the replicated measurements for each treatment were completed, droplet size statistics were determined for the DV0.1, DV0.5, and DV0.9 which are the droplet diameters (µm) for which 10, 50 and 90%, respectively, of the total spray volume is contained in droplets of equal or lesser size.

The results from this initial droplet size testing are shown in the Appendix A. From this data a subset was selected for testing in a field study scenario. Active ingredient and/or adjuvant treatments were used with the CP 4012 nozzles. Another treatment using 11003 flat fan nozzle was made and served as a reference spray. The rotary nozzles were not used in the field study due to time and boom setup limitations.

The treatment number conventions used for the field study along with the nozzle and spray formulation are below. All treatments were at an airspeed of 137 mph and 2 GPA rate, except for treatment 1 (1 GPA), which was the standard nozzle. The following treatments were selected for the field study. All spray pressures were as listed.

T1 – 11003 FF @ 0° and 43 psi; Water and a non-ionic surfactant at 0.25% (v/v)
T2 – 4012 flat fan at 23° and 38 psi; Headline AMP at 10 oz/ac
T3 – 4012 flat fan at 23° and 38 psi; Headline AMP at 10 oz/ac + ROC at 3% v/v
T4 – 4012 flat fan at 23° and 38 psi; Headline AMP at 10 oz/ac + Superb HC at 0.5% v/v
T5 – 4012 flat fan at 23° and 38 psi; Headline AMP at 10 oz/ac + Vector at 2 lb/100gal
T6 – 4012 flat fan at 23° and 38 psi; Headline AMP at 10 oz/ac + Control at 2 fl oz/100 gal
T7 – 4012 flat fan at 23° and 38 psi; Headline AMP at 10 oz/ac + Precision PX 159 at 0.25% v/v

Treatment 1, the ASABE S572 reference nozzle for the F/M droplet size classification, was used as the baseline comparison for each of the individual treatments. The intent of this work was not to rank the treatments, but rather to compare the decrease in drift relative to the reference treatment.

Wind Tunnel Droplet Size Results

The droplet sizes for the five solutions containing active ingredient were very different from the water and non-ionic solution (Table 1). Overall, volume median diameters (VMDs) ranged from 167.9 to 293.9µm, for all treatments. Similarly, the results for percent of spray volume less than 100 µm in diameter, a potential indicator of the portion of spray most prone to drift, ranged from a high of 21.7% for the reference nozzle to a low of 8.1% (Treatment 7). The addition of both the crop and high surfactant oil concentrates (Treatments 3 and 4) showed minor changes in overall droplet spectrum for the treatments. The guar gum polymer (Treatment 5) resulted in minor increases in the VMDs for the treatments, but significant spreads in the overall droplet size distribution as indicated by the increased relative spans and corresponding lowered $D_{V0.1}$ and increased $D_{V0.9}$ values. The polyvinyl polymer (Treatment 6) showed very little change in the VMD, but had a significant spread in the overall droplet size distribution, shown by the increased relative spans, lowered $D_{V0.1}$ and increased $D_{V0.9}$ values. Both of the polymers increased the percent volumes less the 100 and 200 µm.

Table 1. Atomization results from the high speed wind tunnel test of the treatments selected for field studies (taken from Appendix A).

Trt	DV10 (um)	DV50 (um)	DV90 (um)	RS	%<100 um	%<200 um
T1	65.5	167.9	297.4	1.4	21.7	63.1
T2	100.2	255.7	434.3	1.3	10.0	33.3
T3	105.3	244.3	393.1	1.2	9.0	34.3
T4	108.2	257.4	415.2	1.2	8.6	31.5
T5	90.7	293.9	547.9	1.6	11.7	31.3
T6	78.1	265.3	661.0	2.2	15.5	38.7
T7	111.3	274.2	453.7	1.3	8.1	28.7

AGDISP Modeling

Using the wind tunnel data in Table 1, AGDISP was used to determine the application efficiency (% of applied spray material that deposits in-swath) and the downwind deposition (% of applied spray material that deposits downwind of the intended swath) for the treatments selected for the field study. This data will not be reported in this paper. For more detail on the AGDISP results refer to the following paper - Wind Tunnel and Field Evaluation of Drift from Aerial Spray Applications with Multiple Spray Formulations. Fritz, BK; Hoffmann, WC; Wolf, RE; Bretthauer, S; Bagley, WE. 2011. Journal ASTM Int; Submitted October 2011.

Field Scale Drift Testing

The field testing consisted of the 7 treatments listed earlier. All treatments were applied using an Air Tractor 402B aircraft operated at 137 mph with a spray swath of 67-foot and a release height of 10 feet. Each spray pass was applied such that the spray was active a minimum of 500 feet to either side of the A and D sampling lines. Each of the sampling lines were 300 feet apart. In addition to the spray formulation listed for each treatment, caracid brilliant flavine FFS fluorescent dye (Carolina Color & Chemical Co., Charlotte, NC) was added at a rate of 2.5 g/gallon. The field study was conducted in a field of recently harvested wheat located near College Station, TX (30°33'09.83"N 96°27'17.52"W). Four parallel sampling lines were deployed with 5 in-swath (-20, -15, -10, -5, and 0 m, where 0 m is the downwind edge of the swath) and 4 downwind (5, 10, 25 and 50 m) sample stations per line (Figure 2). All in-swath and downwind deposition samplers consisted of clean 10 x10 cm mylar cards.

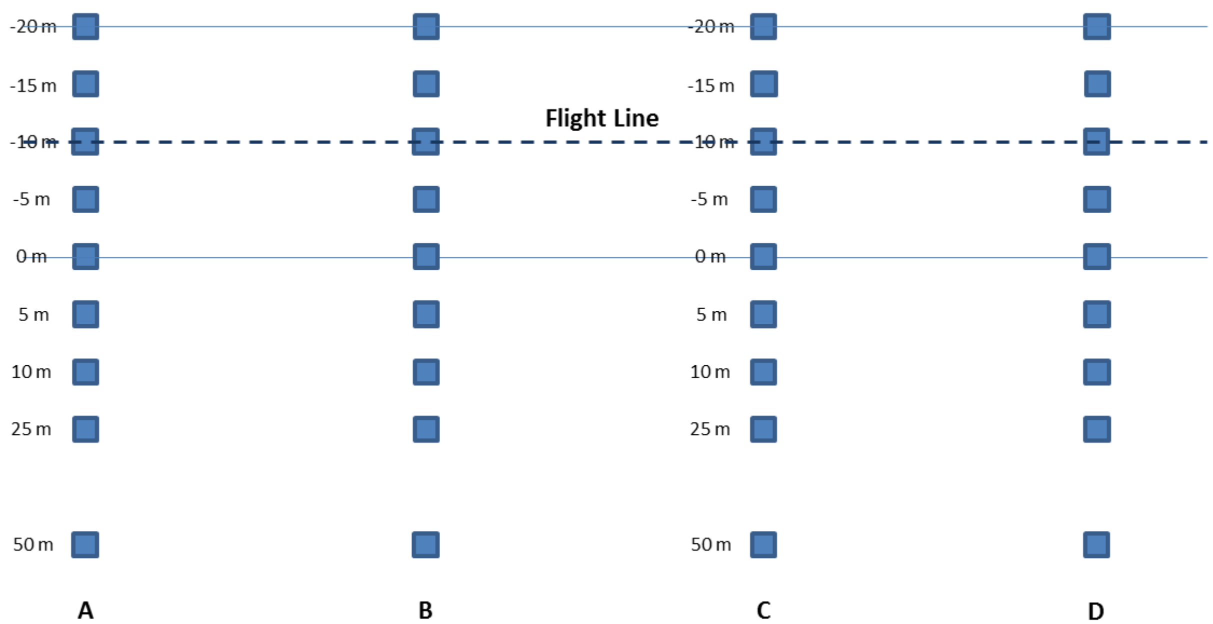

Figure 2. Field drift study layout

The field testing was conducted July 10, 2011. Three replications were completed for each treatment.

Prior to each treatment replication, mylar cards were deployed by positioning them on metal plates (10 x 10 cm) that were placed onto plywood squares (30 x 30 cm) positioned at each sampling location. The plywood squares insured that the samples were horizontal to the ground surface and free from interference or contamination by plant foliage. At the completion of each replication, mylar samplers were collected into individually labeled zip-top bags. All sample bags were labeled with unique identifiers that included treatment, replication number, sample type, location in the field, and serial number.

Meteorological Data

The meteorological monitoring equipment deployed during the field studies malfunctioned requiring the meteorological data to be obtained from the USDA ARS APMRU Minilab Weather Station also located in the Brazos bottom approximately 4 miles from the field site used in the study. Temperature and relative humidity (Campbell Modified Vaisala Probe), wind speed (Met-One Anemometer) and wind direction (Met-One Wind Vane) were recorded (Table 2). It should be noted that this station records the data on an hourly basis so individual treatment/rep data are not available. However, wind speeds were consistent during the timeframe of testing each day. Times for each treatment are given in Table 3.

Table 2. Meteorological data for treatment day.

Hour	Avg T (°C)	Avg Relative Humidity (%)	Avg Wind Speed (m/s)	Avg Wind Direction (° coming from)	Wind Direction Standard Deviation (°)
July 10, 2011					
8	25.1	97	1.4	143	10.2
9	27.4	90	1.6	168	28.9
10	29.1	83	2.1	197	29.4
11	30.4	76	1.5	201	58.3
12	31.9	69	1.5	189	55.9

Table 3. Treatment times for each treatment for each day.

Treatment	Time	Flight Line Heading (°)
July 10, 2011		
7	9:12 am	220
6	9:38 am	220
5	10:01 am	270
1	10:28 am	270
4	10:48 am	270
3	11:17 am	270
2	11:35 am	270

Sample Processing and Recovery Analysis

The labeled plastic bags containing the collected mylar samples were transported to the laboratory for processing. Thirty ml of ethanol was pipetted into each bag, the bags were agitated by hand for approximately 15 seconds, and 6 ml of the effluent was poured into a cuvette. The cuvettes were then placed into a spectrofluorophotometer (Shimadzu, Model RF5000U, Kyoto, Japan) with an excitation wavelength of 423 nm and an emission at 489 nm. The fluorometric readings were converted to $\mu L/cm^2$ using a projected area of the sampler (100 cm^2 for the mylar cards) and by comparisons to standards generated using the actual spray solution used. The minimum detection level for the dye and sampling technique was 0.07 ng/ cm^2.

All deposition data was expressed as a mass of dye per area ($\mu g/cm^2$) from which the volume of spray mix per area was calculated using the determined dye mixing rates for each spray tank formulation. The calculated values were adjusted dye recovery rates of 99, 97, 95, 95, 93, 96, and 98% for Treatments 1-7, respectively.

Results for the Field Study

The averaged integrated deposition results for the in-swath, and downwind (5-50 m) data, along with mean separations (Tukey's HSD; calculated using SYSTAT, Version 13, Systat Software, Inc., Chicago, IL) are given in Table 4. The data from sampling lines A-D for all three reps completed were averaged. One of the complicating factors was the variability in the wind direction, as seen in the wind direction standard deviations (Table 2). During the testing, the winds were light and variable and resulted in the sampling and flights lines being reoriented after the first two treatments. This resulted in a significant degree of variability in the field data as well, as indicated by the standard deviations seen across both the in-swath and downwind deposition data (Table 4). This level of variability, consequently, resulted in few significant differences between treatment means. Some very general observations that can be made are that the use of a spray nozzle designed for the aerial platform (the 40 degree flat fan nozzle held with the CP Products nozzle body) results in significantly improved in-swath deposition and decreased downwind deposition, as compared to the reference Treatment 1. Additionally, there are some significant improvements, in terms of increased in-swath deposition and decreased downwind deposition, which can be had with the addition of a spray tank adjuvant as compared with the use of no adjuvant (T2).

Table 4. Integrated deposition data for all treatments across both days and all replications.

	Integrated In-Swath Deposition (-20 to 0 m) (% of Total Applied)				Integrated Downwind Deposition (5 to 50 m) (% of Total Applied)			
	Avg		±	St.Dev.	Avg		±	St.Dev.
1	5.8	a	±	1.6	7.3	b	±	4.7
2	22.6	b	±	5.9	4.9	ab	±	2.4
3	37.0	c	±	13.2	7.4	b	±	4.2
4	22.1	b	±	7.9	6.6	ab	±	2.4
5	33.4	bc	±	13.0	5.1	ab	±	4.0
6	29.4	bc	±	9.6	2.8	a	±	0.9
7	24.3	b	±	10.8	3.0	a	±	1.5

*Means followed by the same letter(s) within each day's in-swath deposition and integrated deposition data are not significantly different. Determined using Tukey's HSD at α=0.05 level.

Discussions and Conclusions

The overall objective of this work was to explore how the addition of different spray tank modifiers into an active ingredient spray mixture impacted the spray characteristics and in-field behavior under aerial application conditions. The wind tunnel tests demonstrated the impact that active ingredient has on the atomization of an agrochemical solution given the significant differences seen between the different solutions tested and the water and non-ionic surfactant “blank” reference spray. Wind tunnel evaluations showed that while the polymers (treatments 5 and 6) tended to broaden the droplet size distribution, the oil concentrates (treatments 3 and 4) had little impact in the presence of a spray solution with a formulated active ingredient. The experimental product (treatment 7) was unique in that it reduced the percent of spray volume less than 100 µm in diameter and did not broaden the droplet size distribution.

The field evaluation portion of the study highlights the difficulty of comparing a large number of spray formulations or treatments under similar conditions. Even though every effort was made to minimize time between replications, there was enough variability to prevent statistical or even observation separation in the treatments. These results have led the authors to conclude that field testing of potential DRTs under aerial application conditions will be cost prohibitive and likely to give highly variable results; therefore, aerial DRT testing and certification should be conducted in high speed wind tunnels at certified laboratories. Wind tunnel evaluations offer a much quicker and inexpensive method for evaluating large numbers of nozzle and spray formulation treatments. Overall the results of this study highlight the need to further investigate the interaction of active ingredient spray formulations and spray tank modifiers under high speed air shear atomization conditions to better understand the potential role and benefit that adjuvants play in aerial applications.

Appendix A. Droplet size data from high speed wind tunnel testing for flat-fan nozzle.

Trt	Nozzle	Deflection	PSI	Airspeed (mph)	Headline* (ml)	Adjuvant*	DV10 (um)	DV50 (um)	DV90 (um)	Relative Span (RS)	%<100 um	%<200 um
1	11003	0 degrees	43	137	0	R11 NIS (43 ml)	65	168	297	1.38	22	63
2	4012	23 degrees	38	137	0	R11 NIS (43 ml)	99	239	403	1.27	10	37
3	4012	23 degrees	38	137	665	n/a	100	256	434	1.31	10	33
4	4012	23 degrees	38	137	665	R11 NIS (43 ml)	103	255	416	1.23	10	32
5	4012	23 degrees	38	137	665	ROC (511 ml)	105	244	393	1.18	9	34
6	4012	23 degrees	38	137	665	SSMSO (511 ml)	89	223	366	1.24	12	42
7	4012	23 degrees	38	137	665	Superb HC (85 ml)	108	257	415	1.19	9	31
8	4012	23 degrees	38	137	665	Interlock (170 ml)	98	227	361	1.16	10	40
9	4012	23 degrees	38	137	665	Interlock (85 ml) + Superb HC (85 ml)	102	234	375	1.17	10	37
10	4012	23 degrees	38	137	665	In-Place (83 ml)	98	228	365	1.17	10	39
11	4012	23 degrees	38	137	665	Vector (40 grams)	91	294	548	1.56	12	31
12	4012	23 degrees	38	137	665	Event (170 ml)	84	282	557	1.67	13	34
13	4012	23 degrees	38	137	665	Rosen DVA 9773 (170 ml)	76	249	470	1.58	16	39
14	4012	23 degrees	38	137	665	Array	92	298	582	1.65	12	32
15	4012	23 degrees	38	137	665	Control (3 ml)	78	265	661	2.20	15	39
16	4012	23 degrees	38	137	665	Precision PX 159-11 (43 ml)	111	274	454	1.25	8	29
17	4012	23 degrees	38	137	665	Precision PX 259-11 (43 ml)	106	262	427	1.23	9	31
18	4012	23 degrees	38	137	665	High Load (85 ml)	109	268	439	1.23	8	30

Appendix A continued. Droplet size data from high speed wind tunnel testing for rotary atomizers.

Trt	Nozzle	Orifice Size, Blade Setting	PSI	Airspeed (mph)	Headline* (ml)	Adjuvant*	DV10 (um)	DV50 (um)	DV90 (um)	Relative Span (RS)	%<100 um	%<200 um
19	ASC Rotary	D-12, 2	23	137	0	R11 NIS (43 ml)	74	190	354	1.47	17	54
20	ASC Rotary	D-12, 2	23	137	665	n/a	71	189	332	1.38	18	54
21	ASC Rotary	D-12, 2	23	137	665	R11 NIS (43 ml)	72	193	348	1.43	17	53
22	ASC Rotary	D-12, 2	23	137	665	ROC (511 ml)	65	171	285	1.29	21	63
23	ASC Rotary	D-12, 2	23	137	665	SSMSO (511 ml)	58	155	265	1.34	25	71
24	ASC Rotary	D-12, 2	23	137	665	Superb HC (85 ml)	72	190	332	1.37	18	54
25	ASC Rotary	D-12, 2	23	137	665	Interlock (170 ml)	57	149	248	1.29	26	75
26	ASC Rotary	D-12, 2	23	137	665	Interlock (85 ml) + Superb HC (85 ml)	61	159	267	1.29	23	69
27	ASC Rotary	D-12, 2	23	137	665	In Place (83 ml)	60	155	260	1.29	24	71
28	ASC Rotary	D-12, 2	23	137	665	Vector (40 grams)	70	227	416	1.52	17	42
29	ASC Rotary	D-12, 2	23	137	665	Event (170 ml)	70	242	475	1.67	17	40
30	ASC Rotary	D-12, 2	23	137	665	Rosen DVA 9773 (170 ml)	56	191	356	1.56	23	53
31	ASC Rotary	D-12, 2	23	137	665	Array	65	227	441	1.66	19	43
32	ASC Rotary	D-12, 2	23	137	665	Control (3 ml)	66	239	549	2.01	19	43
33	ASC Rotary	D-12, 2	23	137	665	Precision PX 159-11 (43 ml)	73	191	331	1.35	17	54
34	ASC Rotary	D-12, 2	23	137	665	Precision PX 259-11 (43 ml)	71	190	333	1.38	18	54
35	ASC Rotary	D-12, 2	23	137	665	High Load (85 ml)	74	196	345	1.38	17	52

*Rate added to a 5 gallon mix (ml).